

**CLAIMS**

We claim:

1        1. A computer data signal embodied in an electromagnetic waveform for producing  
2 a computer readable definition of a photolithographic mask that define a target pattern in a layer  
3 to be formed using the photolithographic mask, the computer data signal comprising:

4            a source code segment for identifying a plurality of features in the target pattern to be  
5 defined using phase shifting, each of the plurality of features comprised of a plurality of edges;

6            a source code segment for placing a plurality of shifter shapes in the computer readable  
7 definition of the photolithographic mask, the plurality of shifter shapes placed proximate to  
8 edges of the plurality of features, wherein the plurality of features includes a first feature having  
9 a first edge and a second edge, the first edge adjoining the second edge, and wherein the plurality  
10 of shifter shapes includes a first shifter shape placed on the first edge and a second shifter shape  
11 placed on the second edge, the first shifter shape and the second shifter shape separated by a  
12 minimum distance;

13            a source code segment for assigning phase to the plurality of shifter shapes according to  
14 phase dependencies and costs to create a plurality of phase shifters; and

15            a source code segment for refining the plurality of phase shifters.

1        2. The computer data signal of claim 1, wherein the source code segment for  
2 assigning phase further comprises a source code segment for branch-and-bound phase  
3 assignment.

1        3. The computer data signal of claim 1, wherein the source code segment for  
2 assigning phase further comprises a source code segment for graph-based phase assignment.

1        4. The computer data signal of claim 1, further comprising a source code segment  
2 for producing a computer readable definition of a second photolithographic mask, the second  
3 photolithographic mask comprising a complimentary mask to be used in conjunction with the

4 photolithographic mask to define the target pattern, the second photolithographic mask defined  
5 using the target pattern and the plurality of shifter shapes.

1 5. The computer data signal of claim 4, wherein the second photolithographic  
2 comprises at least one of a trim mask, a tri-tone mask, an attenuated phase shifting mask, and a  
3 binary mask.

1 6. The computer data signal of claim 1, wherein the target pattern represented as a  
2 computer data signal in a first file format and wherein the computer readable definition of the  
3 photolithographic mask represented as a computer data signal in a second file format.

1 7. The computer data signal of claim 6, wherein the first file format and the second  
2 file format are the same format.

1 8. The computer data signal of claim 6, wherein the first file format comprises a  
2 GDS-II stream format and the second file format comprises a mask data file in a format suitable  
3 for use in mask fabrication machines.

1 9. A photolithographic mask for defining a target pattern in a layer to be formed  
2 using the photolithographic mask, the target pattern comprised of a plurality of features, the  
3 photolithographic mask comprising:

4 a dark field mask having phase shifting openings, the phase shifting openings defined by  
5 a process comprising

6 placing a plurality of shifter shapes proximate to edges of the plurality of features,  
7 wherein the plurality of features includes a first feature having a first edge and a second edge, the  
8 first edge adjoining the second edge, and wherein the plurality of shifter shapes includes a first  
9 shifter shape placed on the first edge and a second shifter shape placed on the second edge, the  
10 first shifter shape and the second shifter shape separated by a minimum distance;

11 assigning phase to the plurality of shifter shapes according to phase dependencies  
12 and costs to create a plurality of phase shifters;

13 refining the plurality of phase shifters; and

14 producing a computer readable definition of the photolithographic mask.

1           10.    The photolithographic mask of claim 9, wherein the placing further comprises  
2 placing the first shifter shape and the second shifter shape such that a cut can be admitted  
3 between the first shifter shape and the second shifter shape.

1           11.    The photolithographic mask of claim 10, wherein the cut comprises an opening  
2 comprised of a substantially square notch that is intersected at an offset on a forty-five degree  
3 ( $45^\circ$ ) angle by a straight neck that ends in a squared off form.

1           12.    The photolithographic mask of claim 10, wherein the cut comprises a minimum  
2 mask manufacturing width opening between two adjacent shifter shapes.

1           13.    The photolithographic mask of claim 9, wherein the target pattern characterized  
2 by one or more of the following: at least eighty percent (80%) of the non-memory portions of the  
3 layer are defined by the photolithographic mask; at least eighty percent (80%) of a part of the  
4 floorplan in the layer is defined by the photolithographic mask; at least ninety percent (90%) of  
5 the layer is defined by the photolithographic mask; all of the features in the critical path of the  
6 layer are defined by the photolithographic mask; all features in the layer except those features  
7 that are not phase shifted due to phase conflicts are defined by the photolithographic mask;  
8 everything in the layer except test structures are defined by the photolithographic mask; and  
9 everything in the layer except dummy structures are defined by the photolithographic mask.